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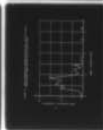
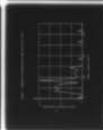
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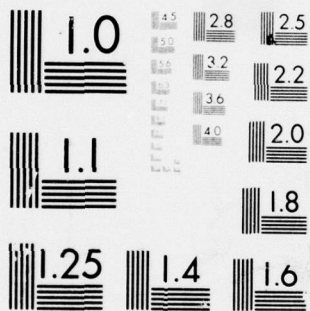
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⑩ BY
CLIFTON G. WRESTLER, JR.

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1. The purpose of the evaluation of a commercial Omega Navigation System was to determine the ability of the system to fulfill the Navy's requirement for long-range overwater navigation for the C-118 aircraft.
2. Reference (a) was an interim report on the evaluation.

F. G. Mitchell
F. G. MITCHELL

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C-118 WSM 1-78

EVALUATION OF A COMMERCIAL OMEGA NAVIGATION SYSTEM
INSTALLED IN THE C-118 AIRCRAFT

BY
Mr. CLIFTON WRESTLER, JR.

ABSTRACT

A Commercial OMEGA Navigation System (ONS) Litton LTN 201, was flight tested to determine the suitability of the system to meet the commercial specifications and the Navy's long-range overwater navigation requirements for the C-118 aircraft. The ONS on the C-118 aircraft had a position error of less than 1 nautical mile (commercial spec error no greater than 7 nautical miles) for the three areas of operation, CONUS, Caribbean and Mediterranean. Signal to noise ratio readings indicate six stations were available for navigation at all times. Seven stations are the maximum number of stations which can be used for navigation due to algorithms in the LTN 201. In the Mediterranean area, seven stations were available for navigation in 85% of the samples taken.

No point estimate can be made on the reliability of the ONS. With approximately 150 flight hours, there were no failures.

A Commercial OMEGA Navigation System will satisfy the long-range overwater navigation requirement in the Atlantic, Caribbean, and Mediterranean for the C-118 aircraft.

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INTRODUCTION

1. BACKGROUND. The OMEGA Navigation System (ONS) operates with land-based radio transmitters operating in the very low frequency (VLF) band of the radio spectrum. The eight transmitters which comprise the present worldwide network is operational with all stations operating. One station, however, is in a temporary location transmitting at one-tenth power. A commercial Litton Aero Production OMEGA Navigation System, LTN 201, was installed in a C-118B for an operational evaluation by an operational squadron.

2. PURPOSE. The purpose of these tests, as delineated in reference (a), was to evaluate the suitability of a commercial ONS to fulfill the Navy's requirement for long-range overwater navigation, to evaluate position accuracy and reliability of the LTN 201 ONS. This report presents the test results, and it also describes the installation and the operational problems encountered. Interim test results were reported in reference (b).

3. DESCRIPTION OF EQUIPMENT

a. AIRCRAFT. The aircraft selected for test was C-118 BUNO 131609 assigned to VR-54 DET Atlanta. Aircraft was selected because it is in good material condition, physical location with respect to the vendor's technical support offices and the willingness of the squadron to participate in this evaluation. The C-118B aircraft used was standard configuration. Navigation equipment for this aircraft consists of AN/APN 70A (inoperative due to LORAN A transmitter shutdown), TACAN VOR/DME, sextant and driftmeter. The main electrical power of the aircraft is supplied by four engine-driven generators supplying 24-28 VDC and up to 300 AMP each. The aircraft is equipped with two inverters rated at 2800 volt-amps to provide 115 volt 400 HZ power.

b. OMEGA NAVIGATION SYSTEM, LTN 201

(1) DESCRIPTION. The Litton LTN 201 OMEGA Navigation System is a worldwide, all-weather, navigation aid which is made up of three components: The Receiver Processor Unit (RPU), the Control Display Unit (CDU), and the Antenna Coupler Unit (ACU). The LTN 201 displays present position in latitude/longitude coordinates. It also provides information of track angle, ground speed, heading, drift positions, distance and time to waypoints, and wind direction and velocity. In addition, the system has a backup dead reckoning (DR) mode based on the available aircraft velocity and heading. Switch over to the DR mode is automatically initiated when the number and quality of received OMEGA signals is below that required for position tracking and navigation.

The LTN 201 initiates automatic synchronization and aligns itself with the transmitted OMEGA signal patterns. Initial position and time/date are required to be entered, the LTN 201 then selects the OMEGA stations to be used for position and navigation automatically. The LTN 201 uses all available signals which pass the programmed tests.

After the system is initialized, the operator enters the latitude and longitude of the selected waypoints and destination. The LTN 201 can navigate automatically from waypoint to waypoint and it can provide continuous navigational data. The navigator can change flight path at any time and use the navigation computation capability of the LTN 201 to assist in preparation of necessary information. The operation of the LTN 201 is described in reference (c).

(2) SYSTEM MECHANIZATION. Various means of processing the signals are currently in use by the various OMEGA manufacturers. The LTN 201 uses the RHO-RHO-RHO (Direct Ranging) mechanization. It uses the phase measurements from three stations to solve the three dimensional problem of local oscillator phase and two dimensional position. Lane ambiguity is inherent in all OMEGA systems. In a direct ranging system, the lane width is the wavelength of the frequency. Thus the lane width is approximately 144 nautical miles. The lane ambiguity is not a problem in the LTN 201 if the position estimate is accurate to within 70 nautical miles.

The LTN 201 measures the phase angles of the incoming signals and compares them to the expected phase angles at the given location. The LTN 201 uses an internal calibration loop and a filter to ensure that the phase measurement error contribution to the total error is much less than one nautical mile. A more detailed description of the LTN 201 is found in reference (d).

4. SCOPE OF TESTS. The LTN 201 was installed in a C-118B aircraft BUNO 131609. All recordings were taken manually. The C-118 aircraft does not have a true airspeed computer. During the initial flights, the true airspeed had to be inserted through the keyboard. In later flights, the true airspeed was fed into the RPU through a calibrated syncro. The aircraft was operated by the assigned squadron in support of fleet operations and normally scheduled training flights. Data was gathered during approximately 150 flight hours.

5. METHOD OF TESTS. The majority of the flight hours and data points were accumulated during the 1-16 July deployment to the Mediterranean. A flight to Puerto Rico and a flight to Mexico were the only other OCONUS flights made. Appendix A lists the OMEGA transmitter sites operational during May-July 1978 tests. There were no significant transmitter outages which occurred during the evaluation flights. The

LTN 201 selects the most distant OMEGA transmitter for calibration and thus it is not available for navigation.

The aircraft geographic position was determined by visual, electronic (radar, VOR, TACAN) and celestial fixes. The most accurate fixes are the visual mark-on-top over surveyed targets, such as navigation aids facilities and airport thresholds.

6. CHRONOLOGY. Dates of significant events during the evaluation are as follows:

- a. Meeting CNO (OPNAV 506)/C-118 WSM (0515) on 23 March 1978. Decision to evaluate OMEGA made.
- b. CNAVRES NEW ORLEANS LA 201919Z APR 78 authorization to prototype aircraft.
- c. 28 March 1978 skin mapping completed.
- d. 8-9 May 1978 LTN 201 installed.
- e. 12 May 1978 crew training.
- f. 13 May 1978 first checkout flight.
- g. 1-16 July 1978 Mediterranean deployment.
- h. 25 July 1978 evaluation completed.
- i. NAVAIREWORKFAC NORFOLK VA 021214Z AUG 78 Interim Report
- j. VR-54 DET ATLANTA GA 311401Z AUG 78 squadron reports aircraft restore to original configuration.

RESULTS AND DISCUSSION

7. INSTALLATION. The three components which comprise the LTN 201 were installed as follows:

a. The antenna coupler unit was located on the underside of the aircraft. It was on the vertical line of symmetry at station 780 and it is shown in figure 1. The location was determined by skin mapping in accordance with procedures of reference (e).

b. The pallet mounted receiver processor unit was located in the forward head which had been converted to a locker. The location is not significant to the operational performance of the RPU but the locker provided physical security of this equipment which was on loan to the U. S. Navy. Figure 2 illustrates the RPU installation.

c. The control display unit (CDU) installed for operation by copilot was tried. Due to size of CDU, the only convenient location was on the glare shield. Figures 3, 4, and 5 show the location of the CDU and impact on outside view. The final location of the CDU when evaluated was at the flight communication operator's station. The true airspeed syncro was located directly over the CDU. Figure 6 illustrates the installation. The syncro was provided to make the manual true airspeed entry easier and faster.

d. The primary power for the LTN 201 was taken from the autopilot circuit. The compass input for the autopilot was used as the heading reference input to the OMEGA. In order to complete the installation, the true airspeed and heading input valid signals had to be rigged with 28 VDC in order for the internal circuits and check subroutines of the LTN 201 to work properly.

8. SKIN MAPPING RESULTS. Skin mapping was accomplished in accordance with reference (e) instructions. North Dakota Station was off the air for the duration of the skin mapping. This resulted in much time being spent verifying all circuits and rechecking the operation of the test equipment. Also, the signal to noise measurements were not accomplished. Skin mapping was accomplished by working with noise levels only. The noise levels are shown in table 1.

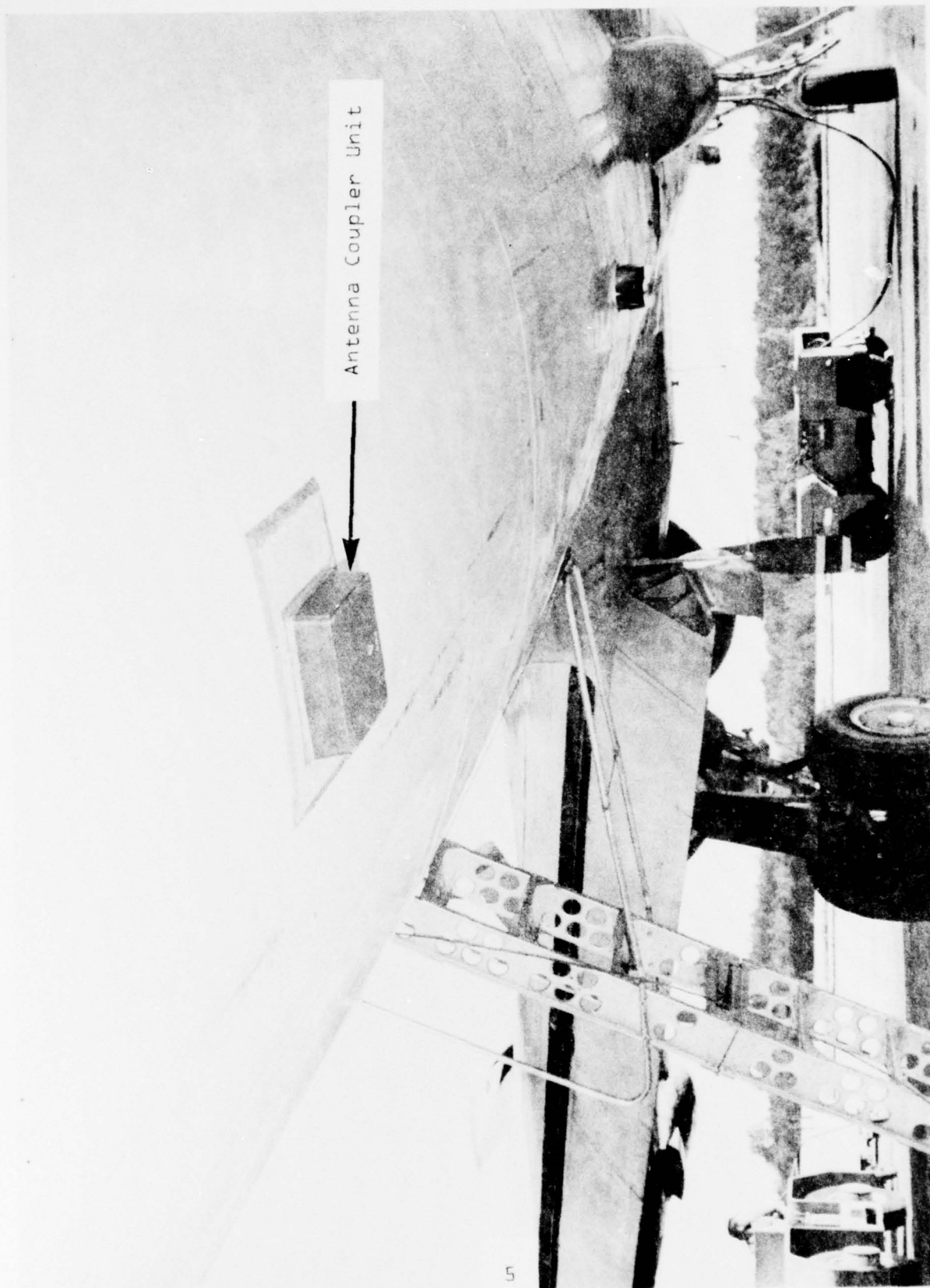


FIGURE 1 Omega Antenna Coupler Unit mounted on underside of aircraft at Station 780.

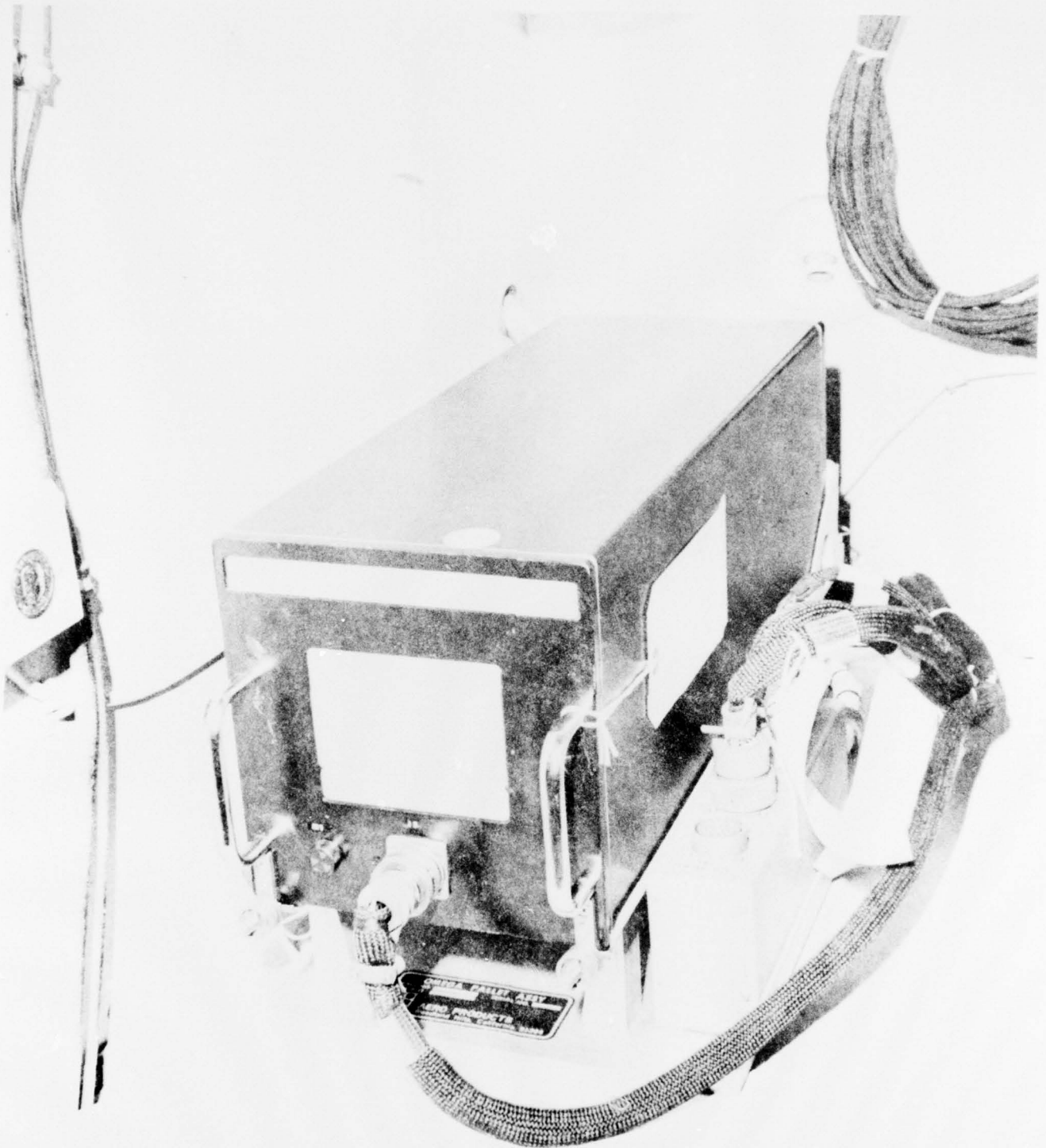


FIGURE 2. Omega Receiver Processor Unit installed.

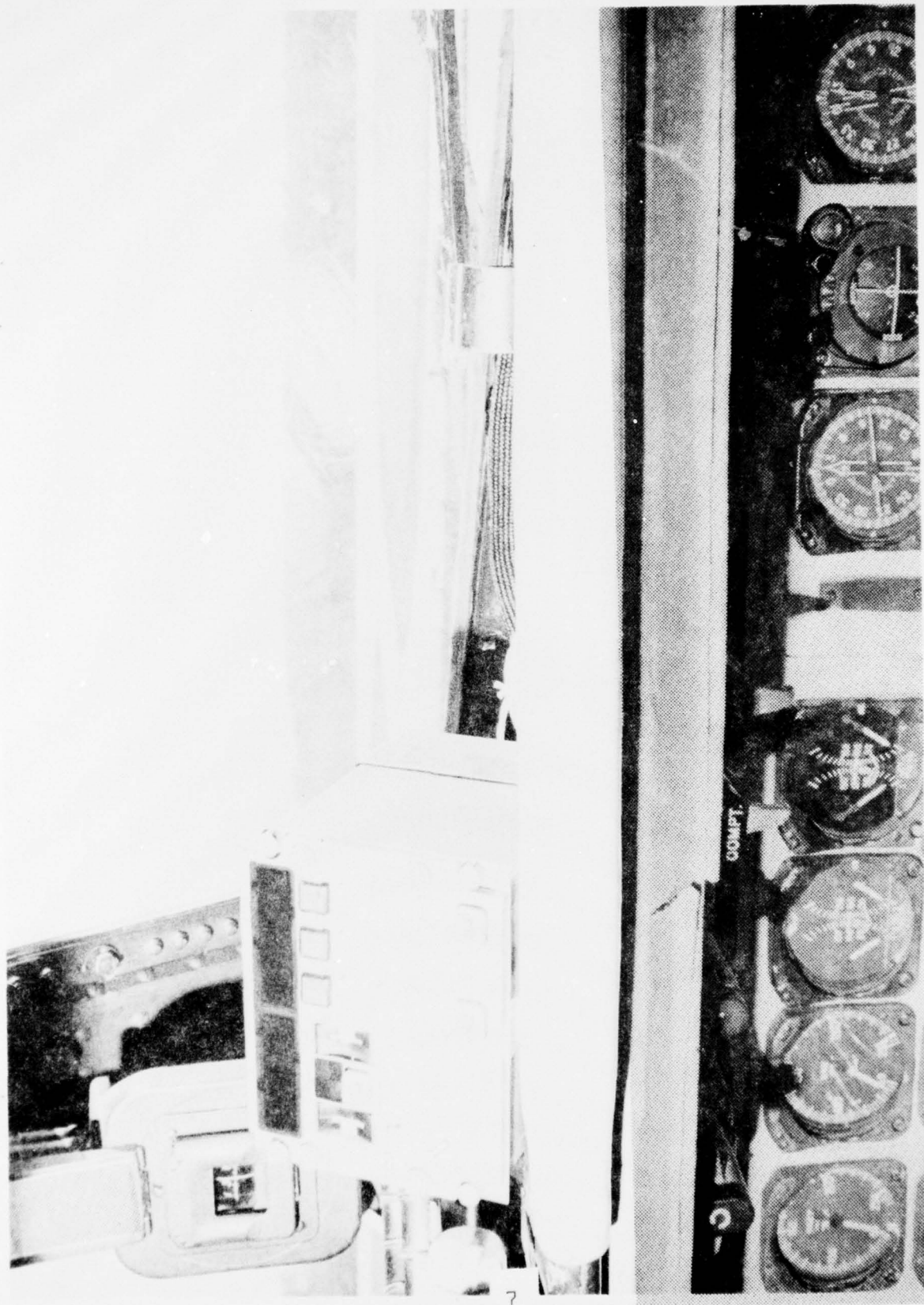


FIGURE 3. Omega Control Display Unit mounted on glare shield as viewed from copilot's seat.

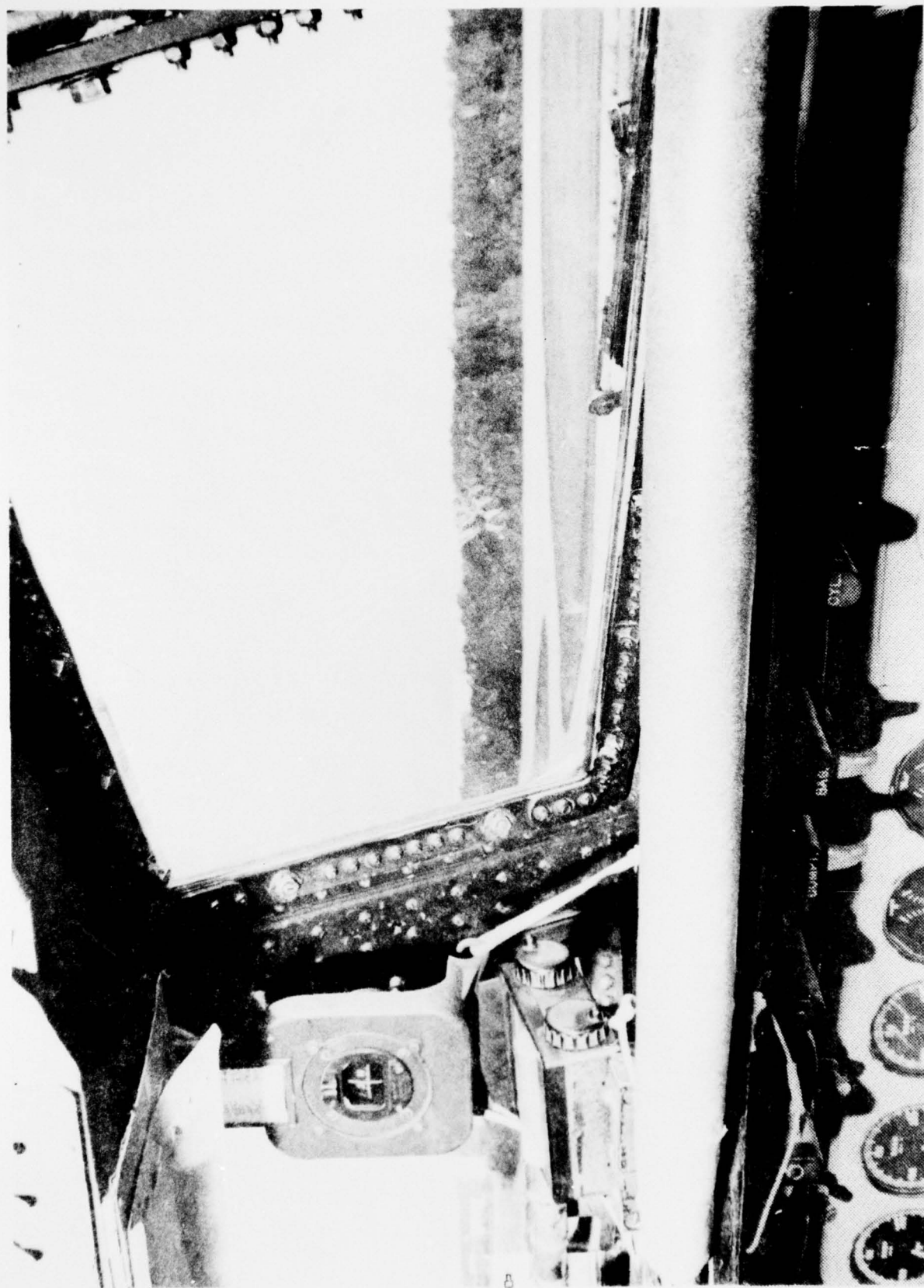


FIGURE 4. View from copilot's seat without Omega CDU.

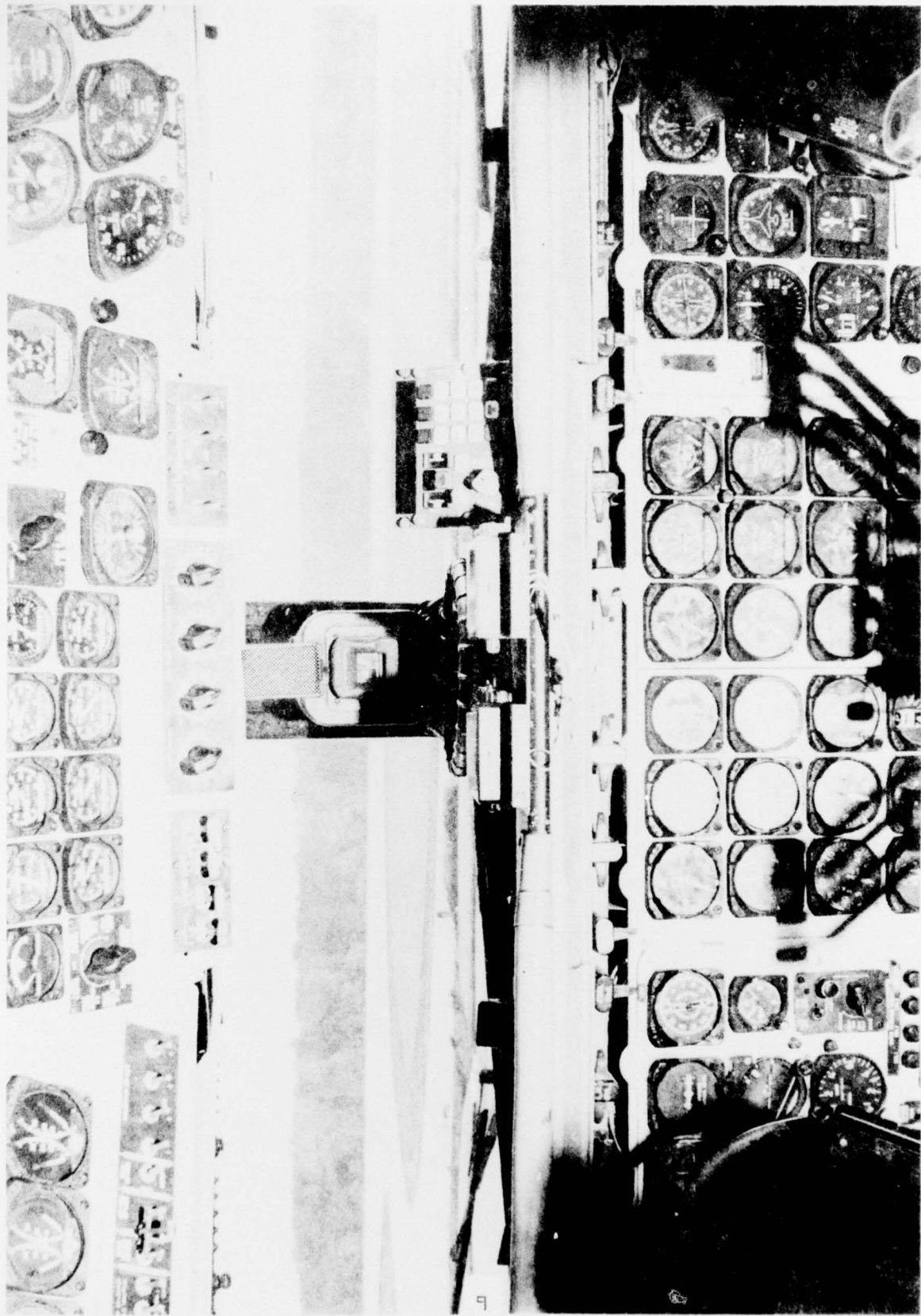


FIGURE 5.

Omega Control Display Unit mounted on glare shield as viewed from engineer's position.

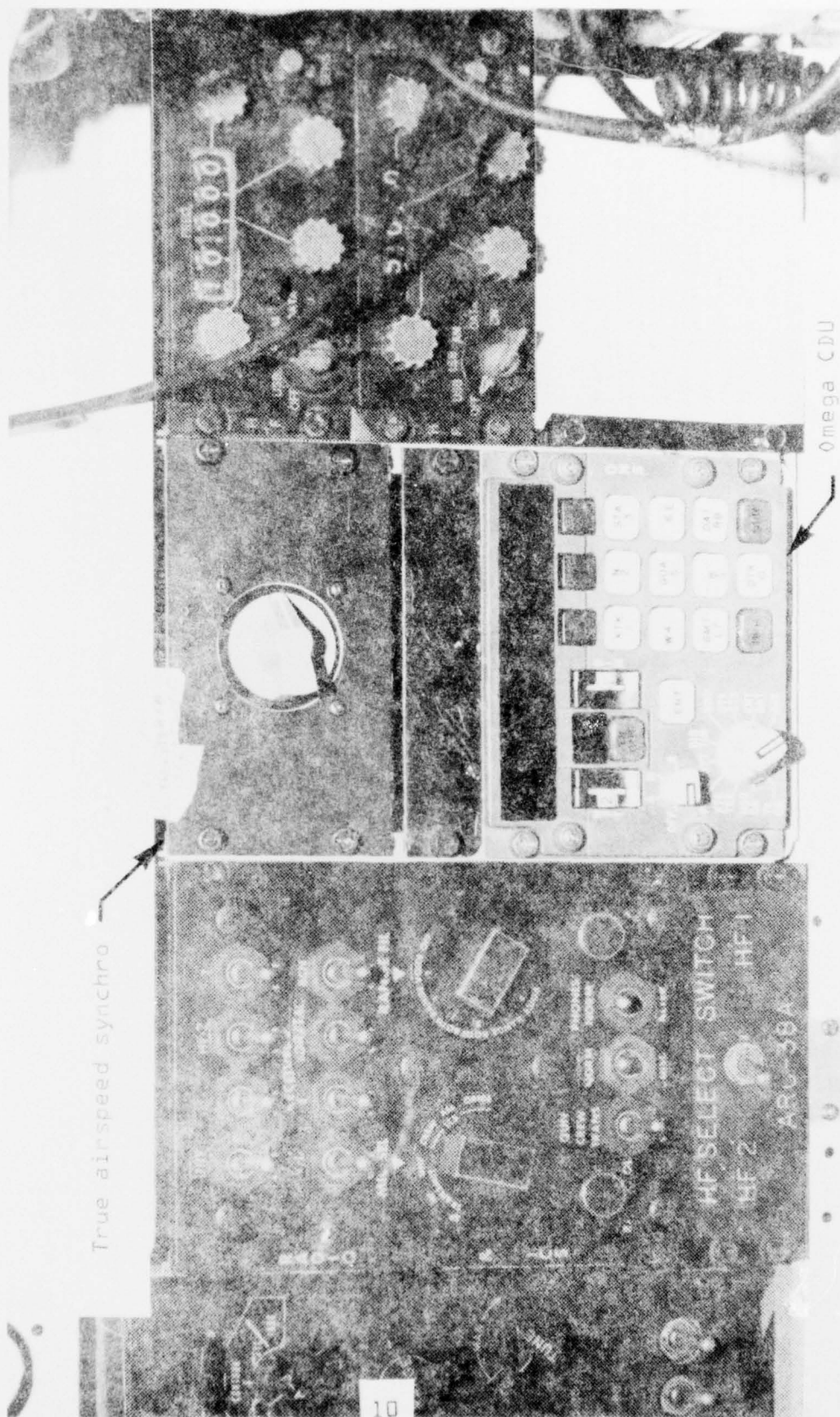


FIGURE B. Omega Control Display Unit mounted at navigator's station.

TABLE 1
SKIN MAPPING TEST RESULTS

Location		Noise Level db down		
		10.2 KHZ	13.6 KHZ	11.33 KHZ
	Loop 1	90	90	90
Background	Loop 2	90	90	90
STA 780	Loop 1	80	80	80
Beneath	Loop 2	85	80	85
STA 260 Top	Loop 1	60	55	65
(Typical reading on top)	Loop 2	75	80	80

9. DATA

a. COLLECTION. The data were collected by navigators who were not fully trained as to the operation of the LTN 201 or in the filling out of the data sheets. This resulted in loss of data collecting opportunities and in the loss of data points taken since the type of fix is not identified. This however, is not considered significant to the evaluation in that more than the minimum required number of data points were collected. The test plan requested collection of data to evaluate some of the navigation computations of the LTN 201. Due to using manual data collection methods, it is not possible to collect the data that would be accurate and meaningful. Since this were secondary to evaluating the position fixing accuracy of the LTN 201, the data was not collected. The signal quality from all eight stations was recorded at various times during the evaluation. The LTN 201 uses the most distant station for calibration and cannot be used for navigation. It does provide a reference which together with the hardware and software make Signal to Noise Ratios (SNR) as low as -9 db available for navigation.

b. REDUCTION. The position data collected were grouped according to the type of fix. Visual mark-on-top over surveyed targets is the most accurate way of determining the geographic position of the aircraft. In flight, the aircraft driftmeter was used to determine the geographic position of the aircraft. The altitude of the aircraft and the field of view of the driftmeter were used to ensure that the aircraft was no greater than 1/2 nautical mile from the surveyed point. The fixes using TACAN, VOR, and unroute radar are considered less

accurate and were grouped separately. The data taken where no information as to how the fix was obtained were not used even though the accuracy is comparable to the accuracy obtained for remainder of evaluation.

The signal quality data were recorded near the waypoints and at the airports. The LTN 201 can display SNR for each station and each of the three frequencies. For statistical purposes of this report, the lowest SNR for the three signals from each station was taken as the value for the station. This gives the pessimistic value for signal quality.

10. DISCUSSION

a. TEST. The 55 mark-on-top data points showed an average error of 0.76 nautical miles with the standard deviation of 0.4457. Within this population there were seven data points taken at night. These seven showed the average error to be 0.50 nautical miles. The sample probability distribution is shown in figure 7. The 40 electronic data points showed an average error of 0.77 nautical miles and a standard deviation of 0.3287. The sample probability distribution is shown in figure 8. Figure 9 shows the probability distribution for the combined data represented in figures 7 and 8. Signal quality data appears in table 2 to portray the percent of samples for a given minimum value of SNR and the minimum number of stations which meet SNR on all three frequencies. All 96 samples were included.

TABLE 2

Percent of samples for a given signal quality and
number of available stations useful to navigation

Minimum SNR db	Number of Stations					
	2	3	4	5	6	7
+20	89.56	45.82	35.42	0	0	0
+10	92.71	55.21	37.50	1.04	0	0
+5	98.96	89.58	60.41	37.49	1.03	0
+0	100	95.82	88.53	72.91	16.66	2.08
-5	100	98.95	95.83	88.54	73.96	29.17
-9	100	100	100	100	100	87.50

b. RELIABILITY. The squadron was required to report ambiguity conditions, relanes, resets and malfunctions. There were no LTN 201

FIGURE 7. PROBABILITY DISTRIBUTION FOR MARK-ON-TOP DATA SAMPLE

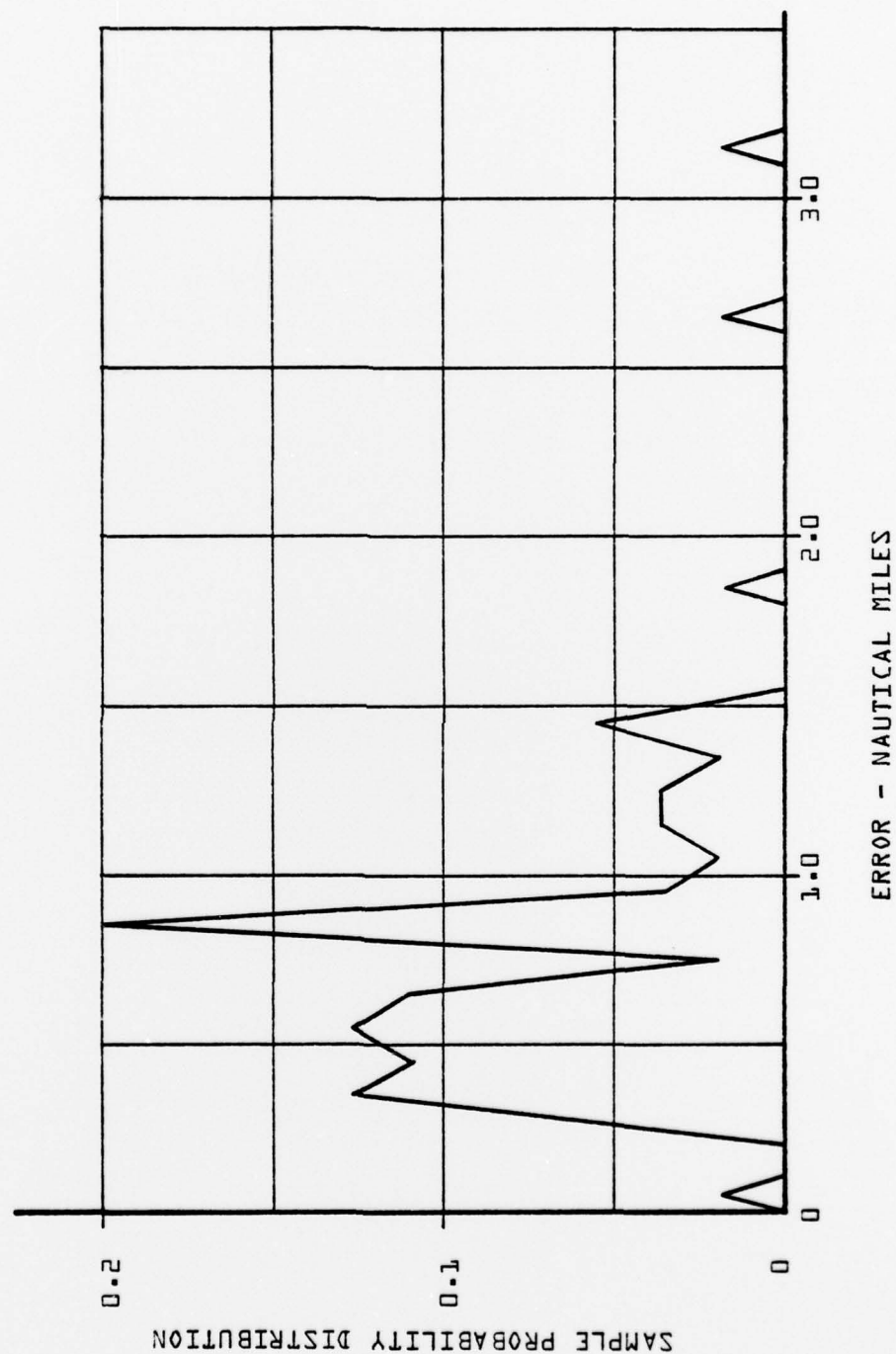


FIGURE 8. SAMPLE PROBABILITY DISTRIBUTION FOR DATA TAKEN USING ELECTRONIC FIXES

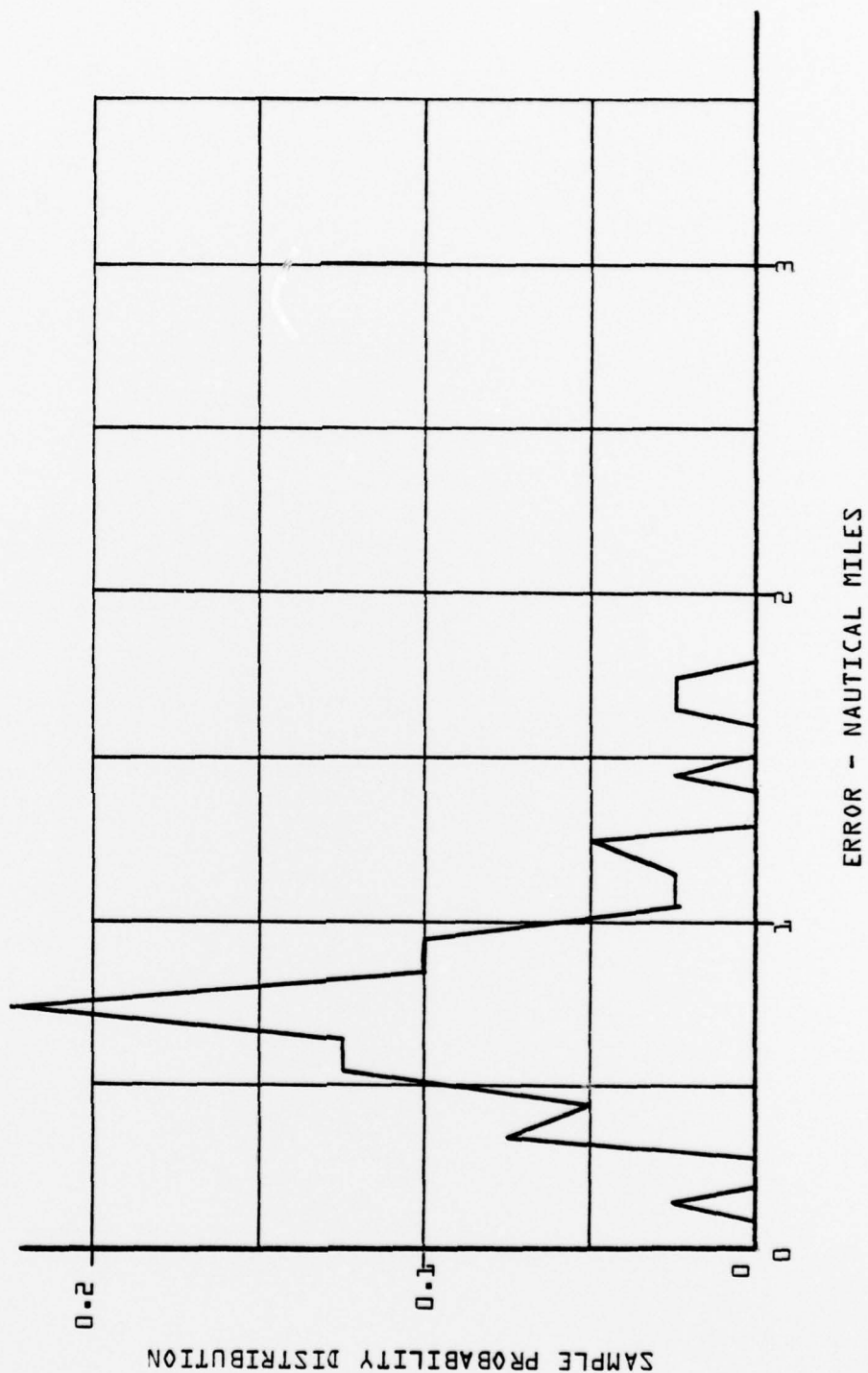
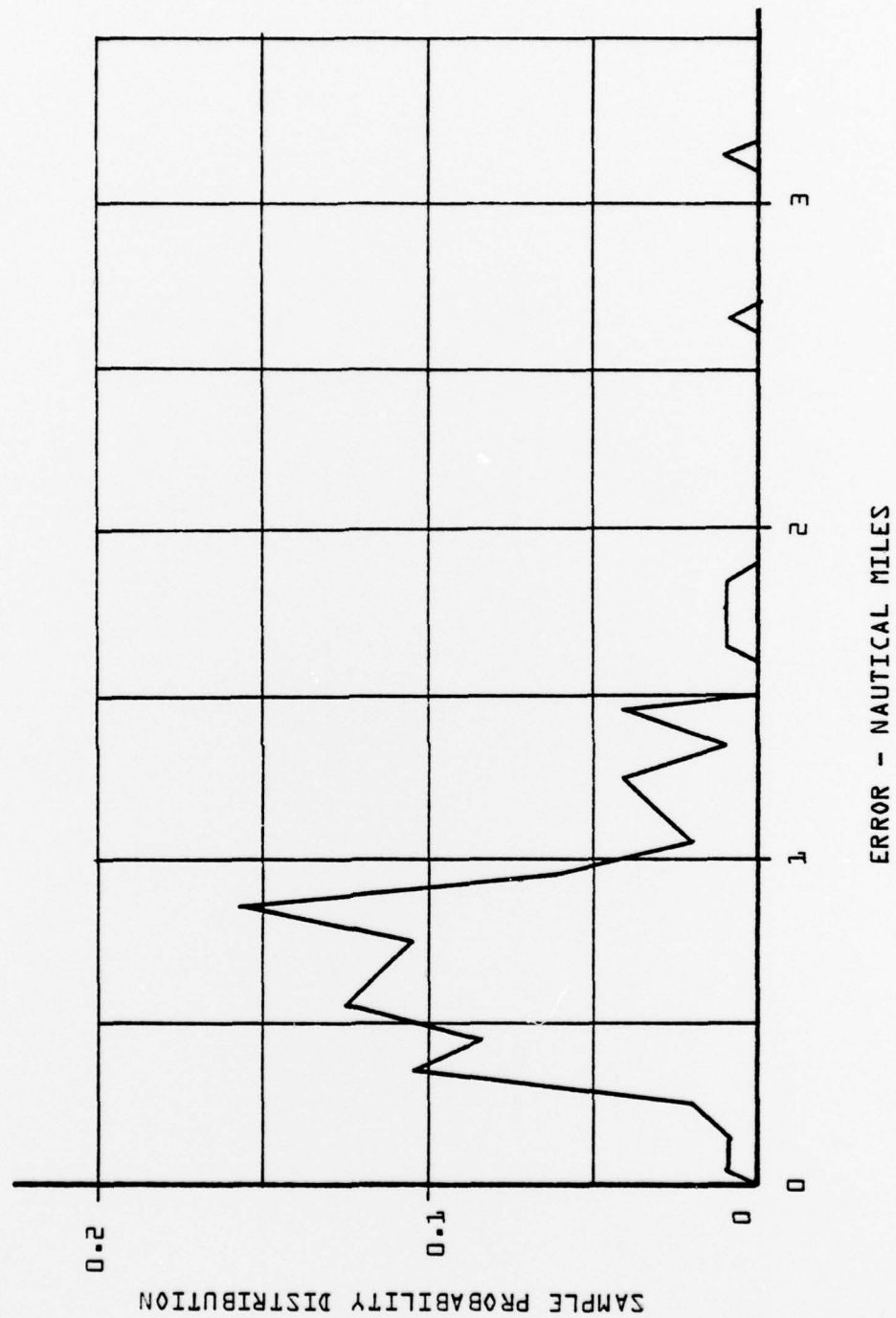


FIGURE 9. SAMPLE PROBABILITY DISTRIBUTION FOR DATA COLLECTED USING BOTH METHODS, MARK-ON-TOP AND ELECTRONIC FIXES



failures. In-flight initializations were accomplished without difficulty by estimating the position of the aircraft. No point estimate can be made as to the reliability of the LTN 201 since no failures or difficulties were encountered.

c. DATA. The data gathered under the mark-on-top fixes were analyzed. The error exceeds to nautical miles in two cases. Both of these cases occurred when the true airspeed inputs to the RPU were not corrected during descent and landing. The Litton Software Program LTN 201 -3-02 has built-in subroutine to check the present position computations with the received OMEGA signals to ensure the error is less than 2 nautical miles. Apparently the subrouting is not working within the specified limits when the airspeed is changing rapidly. The changing airspeed accounts for the greater dispersion found in the mark-on-top data since over half of the data was collected during landings.

The LTN 201 in the C-118 aircraft has almost a certainty of having adequate signal strength to navigate in the Atlantic and the Mediterranean even with the shutdown of any two stations. The aircraft noise levels being extremely low is a large contributing factor.

d. TRAINING. The training provided was in the form of audiovisual presentations which are given to commercial operators. Due to other training requirements, not all the personnel received the complete training. The Navy operators with some hands-on training and by reading reference (c) were able to operate the LTN 201. The operator of the OMEGA would change after every flight and additional hands-on training was required.

CONCLUSIONS

The LTN 201 performed extremely well in the C-118B aircraft. The signal reception based on SNR was excellent to the point that any two stations can be off the air and the LTN 201 still has at least three sets of signals available for navigation. The position accuracy resulted in an average error of 0.77 nautical miles. Crew training and manual should conform with Navy standards e.g., NATOPS, vice airline training.

RECOMMENDATIONS

1. A commercial OMEGA Navigation System with mechanization similar to that found in the LTN 201 will satisfy the long-range overwater navigation requirement for the C-118 aircraft in the Atlantic, Caribbean, and Mediterranean.
2. Training and manuals should be in accordance with NATOPS.
3. A limited evaluation should be conducted to assure accuracies are applicable in the Pacific.

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- A. C-118 WPN SYS MGR spdltr Code 0515/Cw/150 13000
of 11 May 1978
- B. NAVAIREWORKFAC NORFOLK VA 021214Z AUG 78
- C. "LTN 201 OMEGA Navigation System Pilot's Guide"
Report Number TP01-01 Litton Aero Products,
Woodlan Hills, California, Oct 1977
- D. "OMEGA LTN 201 Technical Description"
Report Number 607001 Litton Aero Products,
Dec 1976 (Revised Sep 1977)
- E. "Installation Instructions, LTN 201 OMEGA Navigation System
457400-01" Report Number TP101 Litton Aero Products
Jan 1977 (Rev 4 Oct 1977)

APPENDIX A

STATION	USABLE FOR NAVIGATION	POWER	LOCATION	
A. Norway	DEC 1973	10KW	66°25'15.00" N	13°09'10.00" E
B. Liberia	FEB 1976	10KW	6°18'19.39" N	10°39'44.21" W
C. Hawaii	JAN 1975	10KW	21°24'20.67" N	157°49'47.75" W
D. North Dakota	OCT 1972	10KW	46°21'57.20" N	98°20'08.77" W
E. La Reunion	FEB 1976	10KW	20°58'26.47" S	55°17'24.25" E
F. Argentina	JUL 1976	10KW	43°03'12.53" S	65°11'27.29" W
G. Trinidad (Temp)	FEB 1976	1KW	10°42'06.2" N	61°38'20.3" W
H. Japan	APR 1975	10KW	34°36'53.26" N	129°27'12.49" W

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